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Proton Flares of 1980 - 1986

Harold Zirin

California Institute of Technology
1201 E. California Blvd.
Pasadena, CA 91125

PROTON FLARES OF 1980-1986

Proton flares from 1980 through May 1986 were studied. The particle events (having proton flux of $10/cm^2/s/sr$ with energy ≥ 10 MeV) and their associated flares are published by the NOAA Space Evironment Service Center in the Solar Geophysical Data. A total of 39 proton events occurred during the time interval, of which 34 associated source flares were identified.

Aspects of the 34 proton flares investigated in the study and the results are listed below:

I. Active Regions In Which Proton Flares Occurred

1. Carrington Longitude of Active Regions

The distribution of active regions where proton flares took place in Carrington longitude shows the largest concentration of 13 regions between 311^0 and 360^0, followed by a 60^0-wide region where no proton flares occurred. The next most active region on the sun is 61-90^0 where 7 proton flares took place. The longitude distribution is consistent with the existence of active longitude (or active zones) on the sun where major flares occur.

2. Proximity of Coronal Hole

Because coronal holes are sources of high speed streams in the interplanetary medium, the proximity of coronal holes to the proton flare producing region is examined to see if the propagation of energetic particles is in any way correlated with high speed streams. We find only 9 coronal holes in the vicinities of 39 regions where proton flares occurred.

3. Phase of the Active Region

In terms of the evolution of the regions during the disk passage: 15 regions produced proton flares before (up to 6 days) they reached maximum development as measured in Ca plage; 7 were at the maximum phase; and 12 were in their post-maximum (again up to 6 days) phase. This suggests that the evolutionary phase of the region in which the proton flare occurs does not seem to be a relavent factor here.

II. Proton Flares and Flares Associated with Interplanetary Type II Bursts

1. Similarity to Flares Associated with Interplanetary Type II Bursts

The characteristics of proton flares are in striking similarity to flares associated with interplanetary Type II bursts identified by Cane (1985). They include the following:

Soft X-ray peak flux: $\geq$ M1
Soft X-ray duration: 90% have durations $\geq$ 4 hrs.
Hard X-ray : gradual,long time profile consisting of multiple bursts
Hα flare size: $\geq$ class 1, no subflares
Associated with coronal mass ejection
Associated with Type II/IV bursts with longer durations

The close associated between proton flares and shock-associated interplanetary (IP) Type II flares is further illustrated by the fact that 50% of the IP Type II flares identified by Cane (1985) are proton flares; the great majority of the remainder also produced energetic protons but at below the threshold level (of 10 particles flux density) to be classified as proton flares.

2. Difference between Proton Flares and IP Type II Associated Flares

Proton flares in general are more energetic than shock-associated flares as evidenced by the peak flux in soft X-rays: of the 45 shock-associated flares form Cane's list of 48 (excluding 2 events from quiet regions and 1 with no SXR data) 46% are class X, the average peak flux of the 45 flares is X1.4; for the 34 proton flares (5 have no SXR data), 56% are class X, the average peak flux is X2.8. This explains why many of the IP Type II flares produced proton enhancement at earth but are below the threshold to be classified as proton flares.

III. Hard X-ray Signatures

72% of the 22 proton flares for which hard X-ray (HXR) data were available have gradual time profile with multiple broad peaks lasting a total of 30 min. or longer. (A survey of 7800 HXR flares observed by the SMM Hard X-ray Bursts Spectrometer during 1980-1985 shows only less than 1.5% are gradual long-duration flares.) In fact only 3 of the 22 have short duration of 10 minutes or less. The gradual type of HXR bursts sources have been found to be located higher in the corona progressing to even higher loop tops accompanied by near constant or increasing spectral hardness (Tanaka, 1986).

IV. The Proton Flare Scenario

It is unclear how the high altitude of the acceleration of particles is related to the gradual and long-duration characteristics of this class of HXR flares. But the high altitude seems to be able to explain a number of phenomena described below:

1. In addition to the familiar two-ribbon type, Hα flare of long duration events often shows complex morphologies of three or four ribbons indicating a second higher field

line arcade overlying an earlier lower arcade (Tang, 1987).

2. Subflares are not capable of producing proton flares probably because subflares involve a small volume and it leaves the the high corona virtually uneffected.

3. Most impulsive flares are not associated with coronal mass ejections. It may be conjectured that short-duration/impulsive HXR flares mostly occur low in the corona with the upper corona untouched. Only a fraction of the impulsive flares is able to affect the high corona, and these are the ones associated with CME.

4. Prominence eruptions are associated with CME because prominence are high in the corona. Some prominence eruptions accompanied by optical flares can produce energetic (but below 10 MeV) particles even though the flares are often much weaker than most solar flares in terms of soft X-ray emissions (Kahler et al. 1986). (It is noted by this investigator that the reported prominence eruptions either associated with IP shocks or associated with energetic particles are the ones accompanied by discernable Hα flares suggesting that these are different from the majority of the prominence eruptions that are not accompanied by Hα flares.)

V. Future Research

The study of proton flares and flares associated with interplanetary shocks suggest that understanding of the gradual long-duration hard X-ray flares is the key to the understanding of solar flares capable of producing outer corona and interplanetary disturbances.

Bai (1986) touched the subject in his study of various aspects of impulsive Gamma-ray flares and gradual gamma-ray flares. But gamma-ray flares are a subgroup of most energetic flares. We find that 1/3 of the gradual long-duration HXR flares are class X flares. It is possible to learn more by studying the average flares to avoid the "big flare syndrome". More X-ray Imaging data are needed to study the HXR sources. However, more need to be studied with existing data. Among others we suggest that a research project on a comparison study of the optical flare charateristics, including morphology and linewidth, of long-duration HXR flares and impulsive HXR flares may shed some light on the difference between the two types.

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